Remarks

Applicant and his representatives wish to thank Examiner Nadav for the thorough examination of the present application and the detailed explanations in the Office Action dated April 1, 2008. Claim 1 has been amended to clarify the limitations regarding the alloy layer and to obviate the rejection under 35 U.S.C. § 112, second paragraph. The Examiner's further concerns have been given serious consideration. However, the present claims are considered allowable over the cited references.

Claims 1, 5, and 36-37 have been amended. Claims 1, 4-5, 8, 22-24, 27-32, and 34-38 are active in this application.

The present invention relates to a bonding pad of a semiconductor device comprising:

a) a via within an insulation layer over a metal line;

b) a barrier metal layer on a surface of the via;

c) a copper layer consisting essentially of copper on the barrier metal layer within the via, the copper layer having vertical side surfaces that contact the barrier metal layer; and

d) an alloy layer on an upper surface of the copper layer within the via, the alloy layer having (i) a top surface that is coplanar with or lower than a top surface of the insulation layer and (ii) vertical side surfaces that contact the barrier metal layer, the alloy layer consisting essentially of copper and a low melting point metal selected from the group consisting of aluminum, lead, and silver (see Claim 1 above).

The cited references do not disclose or suggest, alone or taken together, a bonding pad including a copper layer consisting essentially of copper in a via, an alloy layer on an upper surface of the copper layer having vertical side surfaces that contact a barrier metal layer within the via, and consisting essentially of copper and a low melting point metal selected from the group consisting of aluminum, lead, and silver (see steps c-d above). Thus, the present claims are patentable over the cited references.

The Rejections of Claims 1, 4-5, 8, 22-24, 27-32, and 34-37 under 35 U.S.C. § 112, Second Paragraph

The rejection of Claims 1, 4-5, 8, 22-24, 27-32, and 34-37 under 35 U.S.C. § 112, second paragraph has been obviated by appropriate amendment.

Rejection of Claims 1, 4-5, 23-24, 27-32 and 34-37 under 35 U.S.C. § 102(e)

The rejection of Claims 1, 4-5, 23-24, 27-32 and 34-37 under 35 U.S.C. 102(e) as being anticipated by Matsubara (U.S. 6,890,852) is respectfully traversed.

Claim 1 of the present application may be exemplified by a bonding pad 200 comprising a copper layer 3 *consisting essentially of copper* over a barrier metal layer 10 within a via 100, the copper layer 3 having vertical side surfaces that contact the barrier metal layer 10, an alloy layer 5 on an upper surface of the copper layer 3 having vertical side surfaces that contact the barrier metal layer 10 within the via 100, and consisting essentially of copper and a low melting point metal selected from the group consisting of aluminum, lead, and silver (see, e.g., paragraphs [0011]-[0016], and FIG. 1F).

Matsubara discloses a method of forming a semiconductor device including forming a bump electrode 13 on a solder layer 12 (containing Pb or Sn) over a copper buried wiring 8 for use in a flip chip method (see, e.g., col. 5, l. 47-col. 6, l. 11, and FIG. 1). A bump is a structure that is known in the art of semiconductor manufacturing and is distinct from a bonding pad. Bumps are typically formed over bonding pads on a substrate (see, e.g., Wolf, Silicon Processing for the VLSI Era, Volume 1 – Process Technology [2nd ed. 2000], pp. 857-858, Section 17.5.4, first paragraph; submitted with the Amendment filed January 15, 2008 in response to the final Office Action dated October 15, 2007). Specifically, Wolf teaches that solder bumps (typically containing Pb and Sn) are fabricated directly over bonding pads (e.g., Al bonding pads) in flip-chip technologies (see Wolf, *supra*, pp. 857-859, Section 17.5.4, first-third paragraphs and FIGS. 17-15 and 17-16(a)). Consistent with the understanding in the art, the present claimed bonding pad (see, e.g., bonding pad 200 in FIG. 1F of the present application) is distinct from the solder

layer 12 (containing Pb or Sn) and the bump electrode 13 of Matsubara, which together appear to comprise a flip-chip bump structure as described by Wolf.

Therefore, it appears the only structures disclosed by Matsubara that may be compared with the bonding pad structures of the present Claims are the buried copper wirings. Matsubara discloses copper thick films 10 and 22, and a copper thin films 9 and 21 that are comprised within copper buried wirings 8 and 25, which may be made of pure copper or copper alloys (see, e.g., col. 6, ll. 37-43, col. 9, ll. 10-17, col. 10, ll. 20-22, and FIGS. 1 and 12). However, Matsubara does not disclose or suggest that copper thick film 10 and copper thin film 9 of copper buried wiring 8 are composed of different materials. Nor does Matsubara disclose or suggest that copper thick film 22 and copper thin film 21 of copper buried wiring 25 are composed of different materials. Rather, Matsubara discloses that "*the copper buried wiring*" (e.g., copper buried wirings 8 and 25, which include the thin and thick copper films 9 and 10, and 21 and 22, respectively) may alternatively be composed of copper-Al alloys, copper-Ag alloys, <u>*or*</u> copper-silicon alloys (see, e.g., col. 10, ll. 20-22, and FIGS. 1 and 12). Thus, Matsubara's description of the copper buried wiring structures 8 and 25 does not disclose an alloy layer on an upper surface of a *copper layer consisting essentially of copper* in a via, the alloy layer consisting essentially of copper and a low melting point metal selected from the group consisting of aluminum, lead, and silver, as recited in Claim 1.

Also, amorphous film 29 over copper thick film 10 comprises copper and tantalum (see, e.g., col. 9, ll. 9-28 and FIG. 14), and thus does not represent an alloy layer consisting essentially of copper and a metal selected from the group consisting of Al, Pb, and Ag.

Furthermore, the vertical side surfaces of copper thick films 10 and 22 appear to contact only the thin metal films 9 and 21, respectively (see, e.g., FIGS. 1 and 12). The copper layer and the barrier metal layer of present Claim 1 cannot simultaneously read on the same structure (e.g., thin copper wiring 9 or 21). Therefore, it cannot be argued that the copper thick film (10 or 22) of Matsubara is an alloy layer that is on an upper surface of a copper layer (e.g., copper thin film 9 or 21), ***and*** that vertical side surfaces of the copper thick film (10 or 22) contact a barrier metal layer (e.g., thin copper wiring 9 or 21). Thus, Matsubara is deficient with regard to an alloy

layer on an upper surface of a copper layer, *the alloy layer having vertical side surfaces that contact a barrier metal layer within a via*, as recited in Claim 1.

Therefore, Matsubara is deficient with regard to a bonding pad comprising a copper layer consisting essentially of copper in a via, an alloy layer on an upper surface of the copper layer, the alloy layer having vertical side surfaces that contact a barrier metal layer within a via, and consisting essentially of copper and a low melting point metal selected from the group consisting of aluminum, lead, and silver, as recited in Claim 1.

As a result of the deficiencies explained above, Matsubara does not anticipate the present Claim 1, and the rejection under 35 U.S.C. § 102(e) is not sustainable and should be withdrawn. Claims 4-5, 23-24, 27-32 and 34-37 depend from Claim 1 and thus include all of the limitations of Claim 1. Thus, Matsubara fails to anticipate Claims 4-5, 23-24, 27-32 and 34-37 for at least the same reasons as Claim 1.

<u>Rejection of Claims 8 and 22 under 35 U.S.C. § 103(a)</u>

The rejection of Claims 8 and 22 under 35 U.S.C. § 103(a) as being unpatentable over Matsubara in view of Liu et al. (US 6,638,867, hereinafter "Liu") is respectfully traversed.

As discussed above, Matsubara is deficient with regard to a bonding pad comprising a copper layer *consisting essentially of copper* in a via, an alloy layer on an upper surface of the copper layer, the alloy layer having vertical side surfaces that contact a barrier metal layer within the via, and consisting essentially of copper and a low melting point metal selected from the group consisting of aluminum, lead, and silver, as recited in Claim 1.

Liu discloses a bonding pad 60 that includes an aluminum alloy (alternatively copper) bonding pad segment 54 in a shallow interconnection line 40 (see col. 6, ll. 16-27, and FIGS. 6C-6D) and an aluminum conductive layer 58 over the bonding pad segment 54 (see col. 6, ll. 34-42, and FIG. 6C). Liu further discloses that the conductive layer 58 over the bonding pad segment 54 can alternatively consist of aluminum alloy, tungsten, copper, or a copper alloy (see col. 6, ll. 35-40). Liu does not appear to teach or disclose that the non-aluminum metal in the aluminum

alloy alternative is copper, or that the non-copper metal in the copper alloy alternative is aluminum (see col. 6, ll. 34-40). Therefore, Liu fails to cure the deficiencies of Matsubara with regard to an alloy layer on an upper surface of a copper layer consisting essentially of copper, the alloy layer consisting essentially of copper and a low melting point metal selected from the group consisting of aluminum, lead, and silver, as recited in Claim 1.

Additionally, Liu fails to disclose forming a barrier metal layer in shallow interconnect line 40 (see, e.g., col. 5, ll. 20-36, and FIGS. 5A-5B). Furthermore, conductive layer 58 is not formed within shallow interconnect line 40, and thus would not have vertical side surfaces in contact with a barrier metal layer even if Liu disclosed forming a barrier metal in shallow interconnect line 40 (see, e.g., col. 6, ll. 16-42, and FIG. 6A-6C). Thus, Liu fails to cure the deficiencies of Matsubara with regard to a bonding pad comprising a copper layer consisting essentially of copper in a via, an alloy layer on an upper surface of the copper layer, *the alloy layer having vertical side surfaces that contact a barrier metal layer* within the via, and consisting essentially of copper and a low melting point metal selected from the group consisting of aluminum, lead, and silver, as recited in Claim 1.

As a result, Liu fails to cure the deficiencies of Matsubara with regard to the device of Claim 1. Therefore, Claim 1 is patentable over Matsubara in view of Liu. Claims 8 and 22 depend from Claim 1 and thus include all of the limitations of Claim 1. Thus, Claims 8 and 22 are patentable over Matsubara in view of Liu for at least the same reasons as Claim 1, and the rejection under 35 U.S.C. § 103(a) should be withdrawn.

Conclusions

In view of the above amendments and remarks, all bases for objection and rejection are overcome, and the application is in condition for allowance. Early notice to that effect is earnestly requested.

If it is deemed helpful or beneficial to the efficient prosecution of the present application, the Examiner is invited to contact Applicant's undersigned representative by telephone.

Respectfully submitted,

/Alec B. Plumb/

Alec B. Plumb
Reg. No. 56,433

401 W. Fallbrook Avenue, Suite 204
Fresno, California 93711
(559) 432 - 6847

ADF:wkn